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PROGRESS REPORT

Period of September 1, 1963 to September 30, 1963

Contract No. AF 33(600)40280

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A F-101 FLIGHT TEST

Four radar flights were made this month. A crossed field amplifier transmitter failure prevented mapping on flight S-76. All flights were made with a new transmitter and recorder from 40,000 feet altitude. Increased transmitter power and improved recorder resolution resulted in smoother, more uniform video presentation on correlated film.

Street patterns, streams, roads, bridges and mountain ridges in the Harrisburg, Pennsylvania region were produced on flights S-73 and S-74. Typical dot sizes on correlated film are 5 to 10 mils (19 to 37 feet range and 25 to 50 feet azimuth), with 2 mil (9.8 feet) azimuth separation have been detected.

PRIMARY FILM EVALUATION

A range mark generator has been added to the radar. Range marks are triggered by the recorder data flash mechanism and appear as lines across the width of the film. Each mark has a range dimension of 10 mils and the interval between each mark represents 9.78 microseconds (0.8 miles) in time. The time duration of the mark is one second.

Spacing between marks on the primary film varied between 0.67 and 0.75 inches, indicating the non-linearity of the recorder range sweeps. The maximum relative spot displacement error measured at any point between the first and last range marks was 1.5% on both the near and far ranges. Between equivalent points on the data from Itek included in the May progress report the error was 2.2%.

A 200 cycle range jitter was detected on the range marks on flights 73, 74 and 75 and on video recorded on flight 74. This jitter was caused by the oscillator in the recorder high voltage power supply being in a free running condition. The difference frequency between the oscillator and the synchronizing pulses was 200 cps which was super-imposed on the recorder centering and deflection coils, thus causing the range trace jitter. The power supply has been adjusted to oscillate at the system PRF and eliminate the jitter.

Film speed operation was checked by comparing aircraft ground speed and data flash spacing. The ratio of these two factors did not vary by more than one per cent during a six minute run. However, the film drive exhibits roughness as indicated by non-uniform film density in azimuth.

After the radar operator attempted unsuccessfully to obtain doppler frequency tracker lock-up on each flight, he switched radar operation to MANUAL mode. During flight S-73, too low a variable frequency (internal offset) caused a high doppler-offset difference producing "oatmeal" frequencies which approached and exceeded the high frequency limit of the recorder band-pass, resulting in weak high frequency video registration on film. On flight S-74, a 0.5° or greater left drift angle was encountered. To compensate for this, either the antenna should be pointed up in pitch or the system variable fequency oscillator should be set below the radar reference frequency. However, the VFO was set 350 cps above the radar reference during this flight. When the aircraft drift angle was 1.5° left, the doppler frequency at the center of the antenna beam was approximately 900 cps. A VFO setting of 350 cps above the radar reference means the actual offset was approximately 1200 cps, precluding video recording.

Video recorded during flight S-75 covered the entire range on the film. This complete range coverage may be attributed to the increased transmitter power. Also, the radar operator attempted to maintain an actual offset frequency of 150 cps by manually controlling the VFO and pod position. This exercise resulted in a dense "oatmeal" recording with many zero type holograms. Zero holograms are caused by too low an offset frequency. The dense "oatmeal" recording precludes accurate measurement of the highest hologram frequency components, but it can be seen that this frequency exceeds 200 cps.

CORRELATED FILM EVALUATION

Time correlation between primary and secondary films is easier and more accurate over previous months operations due to the presence of range marks. Once a land-mark has been established on both films, time correlation consists of counting range mark intervals. On correlated film, range marks appear as dashes of blanked video 10-15 mils in range and 0.3 inches in azimuth.

Both range sectors were correlated on all flights this month. In areas of good correlation, the video level is uniform-better than 40,000 foot flights made prior to transmitter modification. Film recorded this month presents the best comparison of results at 20,000 foot and 40,000 foot altitude obtained to date.

The effect of offset frequency on resolution and dot structure can be seen by comparing two points on film from flight S-75. At the 19th data flash, five mil dots with 5 mil azimuth separation are apparent on the correlated film. This same point on the primary film has uniform "oatmeal" with holograms starting at zero, indicating a proper offset frequency. At the 21st data flash, dots are smeared in azimuth and oblique to the right. The corresponding point on the primary film has many holograms passing through zero, indicating too low an offset frequency.

At one point on S-75 correlated film, an exact double image of two parallel bridges is recorded. This is a case of the offset frequency being near zero, and the correlator is detecting both sides of zero holograms.

Dots are enlarged and fuzzy due to range trace jitter. Instead of the leading edge of hologram components being vertical they are oblique. This presents a larger leading edge for the correlator to see and results in an enlarged fuzzy dot.

INSTRUMENTATION

Temperature data has shown the heat exchanging equipment in the new transmitter to be adequate at 40,000 feet, the test altitude. The ambient air inside the pressure vessel was 34°C to 37°C, 12°C to 18°C warmer than the ambient in the missile bay area of the aircraft.

No analysis of vibration data was done this month because very little data was obtained. A quick-look at the time history indicates a major component of 178 cps exists. This may be the cause of 180 cps striping on recorder film. Three axis vibration data from the recorder feet will be available next month.

Failures in the aircraft doppler navigator prevented obtaining accurate ground speed and drift angle data. Also, erratic DFT operation prevented the determination of in-flight offset frequency.

The CEC oscillograph functioned properly on all flights but trouble was experienced with the tape recorder. After brake and tape tension adjustments were made, tape recorder operation was satisfactory

SYSTEM

Poor doppler frequency tracker operation was encountered because of low AC signal gain and low dc antenna servo gain. This problem is being investigated.

The flight test CFA transmitter is operating at approximately one-third its specification power and its output pulse is not optimum. Approximately 20 minute transmitter warm up is required before the CFA transmitted pulse and the TWT current pulse both fall within the acquisition range of the transmitter servo. When CFA and TWT coincidence is obtained, the transmitter servo operates satisfactorily.

Aircraft down time was utilized to conduct system tests with primary power of 525 cps. All systems operated normally. There was a slight increase in primary power required at the higher line frequency. Volt-amperes required by the system was

	Frequency	Volt Amperes	Power Factor
Regulated Power	400 cps	170	.93
Unregulated Power	525 cps	3700	.984

B AIR FORCE FLIGHT TEST PROGRAM

The antenna mock-up was shipped to the customer to check fit in the initial installation stages. Design of the waveguide between the transmitter and antenna has started. Ten joints required to fabricate the waveguide bends.

Information was received on the antenna mounting and servo actuator. A spare actuator having similar but not identical performance to the flight test unit is expected October 15th and will be used in the antenna servo tests.

The antenna actuator transfer characteristic was found to be different than assumed in the design of the position servo loop. Final configuration is not yet determined, but it appears a minor feedback loop is required to be added.

Plans for the instrumentation and mode programming are becoming firm. A basic pulse will provide synchronization for the digital recorder. Pulses at one-tenth this rate will be coded by the instrumentation and provide synchronization for the recorder data flash and the CEC recorder. Further division of this basic rate will provide timing for the mode programmer, which will automatically schedule normal operation and pre-arranged mode changes such as switching offset frequency, operating with zero pitch and yaw inputs, and changing IF limit level. The programmer will be initiated from the FILM position of the radar control and the sequence may not be altered in flight. Initial set-up would be to provide normal operation half of the time with 11 other modes interspersed. As confidence increases in the system performance and system configuration is finalized, the number of modes will be reduced, increasing normal operation time.

A CEC analog recorder will be added to the frame to monitor critical points in flight. Much work remains to integrate the instrumentation and the programming with the system.

Cameron Burleson has been established as the first Westinghouse representative in residence to assist the flight test program.

C ENVIRONMENTAL TEST

ANTENNA VIBRATION

Vibration of the antenna was continued to investigate motion of the mechanical beam, waveguide and sticks with vibration applied both parallel and perpendicular to the sticks. The following is a summary of the maximum conditions observed;

Vibration Parallel to Sticks

Location	Frequency	Amplification
Overhang end of beam	90 cps	6
Waveguide power divider at center of antenna	87 cps	15
Sticks at overhang mount	36 cps	28

Vibration Perpendicular to Sticks

Location	Frequency	Amplification
Sticks at overhang end	22 cps	11

Differences in vibration motion were observed between the beam and the sticks at 36 cps in the vicinity of the overhang mount. In the parallel direction, the beam motion was .02 inches D.A. while the stick motion was .16 inches DA. In the perpendicular direction, the beam motion was .2 inches D.A. while the stick motion was .024 inches D.A.

Motion differences were observed between sticks in various locations along the antenna. In the parallel direction, the maximum stick motion difference was .077 inches D.A. at 36 cps. In the perpendicular direction this difference was .316 inches D.A. at 22 cps.

ANTENNA TEMPERATURE

The oven for temperature testing of the antenna is being assembled on the antenna RF range.

ELECTRONICS VIBRATION

The traveling wave tube was vibrated in the redesigned chassis. The maximum amplification of the tube package was 10 at 380 cps. To learn more about the TWT during vibration, a fixture was designed to vibrate the tube removed from the chassis. This fixture is now being fabricated.

A fixture to vibrate the single axis platform was designed and is now being fabricated.

D DESIGN EVALUATION

CRT SPOT POSITION MODULATION

A study was made of "The Effect of CRT Spot Position Modulation on Film Exposure", and issued as STM-136. A sinusoidal modulation was assumed, and the resulting waveform of exposure on the film was solved by graphical means for several example conditions. The conditions assumed were for a 2 inch/second film speed, and a 1 mil gaussian spot. For a 400 cps modulation with peak displacement of one mil, the resulting exposure varied -7db and +9 db. For a

200 cps modulation with peak displacement of 0.25 mil, the exposure varied between -1.5db and +1.2 db. A previous study (STM-111) showed that only ±0.6 db could be tolerated, which gives an indication that the tolerable modulation is probably about 0.1 mil at 200 cps, and even less at 400 cps.

SPATIAL FREQUENCY FILTER

A study is well under way of the effect of a spatial frequency filter on system performance. The problem has been programmed on the digital computer simulation, and the correlator output pattern computed for a variety of conditions. The two filters used are a rectangular filter (i.e a pair of knife edges), and a gaussian weighting filter with chopped-off tails. The offset frequency has been varied from -200 to +1000 cps in 200 cps steps, with the filter centered at 400 cps. The gaussian filter is much better in reducing the sidelobe clutter, and is strongly recommended. A third type of filter, which would theoretically be even better, is the Taylor weighting. Due to the difficulty in setting it up on the computer, it has not been programmed, but if it is practical to build such a weighting filter it would no doubt give even better performance than the gaussian.

A computer program for including the effect of the recorder frequency response on the clutter level has also been set up, but runs have not yet been made. This will determine whether the recorder non-symmetry will degrade the improvement gained by the weighting filter.

E RECORDER EVALUATION

Adjustment of the dynamic focus modulation signal for optimum CRT correction can best be done by placing two microscopes on the microscope test fixture rack. Originally an optical attachment to the microscope was considered for looking at the CRT trace center and both ends simultaneously to aid in adjusting the focus modulation. This attachment has been set aside because of complexity of design and cost.

A paper design for an anamorphic attachment to the present 1 x 1 CRT lens has been started. This lens can be placed about 1 inch in front of the capstan without any disturbance or relocation of other recorder optical elements. The purpose of this attachment would be to provide compression of the spot in one dimension. Later in the program the anamorphic image quality based on a computer ray trace will be weighed against a completely new input lens design.

F ANTENNA

RF tests determined that the boresight of both the Number 2 and Number 3 antennas is perpendicular to the radiating face of the antenna. This will make the two antennas interchangeable without boresighting. One of the spare modules requires additional cleaning before electroforming the stick-manifold joint for all six spare modules.

A dummy antenna similar to the actual antenna in size, and weight has been fabricated for the antenna position servo tests.

G RECORDER

Acceptance test for recorder No. 6 has been delayed because of failure of the high voltage power supply during bench test. Acceptance test is now scheduled for October 15, 1963.

Assembly of recorder No. 7 was delayed waiting for components. The Wollensak lens, the capstan roller and pulley assemblies have been received and are being inspected. In addition, Westinghouse must provide a CRT and the status of the high voltage supply is not clear.

Several mechanical design improvements are planned for Recorder No. 7. These include a new magnetic shield covering the film motion detector; a microscope scale and magnifier to determine the trace scale; a solid casting mount for the M3 mirrors, eliminating tilt and yaw adjustments, which are unnecessary and subject to mirror motion under vibration.

KAISER HIGH VOLTAGE POWER SUPPLIES

During September two Kaiser high voltage power supplies have failed during bench tests at Itek. The source of the troubles are the silicon avalanche high voltage rectifier stacks and the precision high voltage dividers.

The rectifier stack has caused a total of two supply failures. The diode manufacturer claims that one breakdown was caused by a crack in the epoxy, which allowed the diodes to become contaminated by the silicon oil.

There have been 4 failures caused by the precision dividers. The high radial electrostatic fields may induce ionization which in turn causes the thin carbon spiral to open. The precision divider network is being changed in one supply to remove the effects of ionization, including improved encapsulation of the resistors.

FILM MOTION MEASUREMENTS

A method of measuring the relative constancy of motion of the film drive has been developed. A nominal 50 cycle per inch sinewave is recorded from the cathode ray tube face. After the film is processed, the length of film is cut into two parts; one part is laid over the other, maintaining the same direction and orientation of the film.

The sinewave recorded upon the film produces a grating. When two sections of such a grating are superimposed at a slight angle to each other, a Moire fringe pattern with approximately sinusoidal distribution of density is produced. If the spacing of lines on each piece of film is exactly the same, these fringes will be straight lines at 90° to the bisector of the angle between the lines of two films. However, if the spacing of lines on one film is different than on the other, the fringe demarcation will tilt at an angle other than 90° to the bisector of the film slant angle. From this consideration it is possible to calculate $\frac{\Delta D}{D}$, the percentage change in line spacing of one film relative to the other, thereby measuring the relative instantaneous change of film speed that occurred during the recording process. This is given by:

$$\frac{\text{delta } D}{D} = \frac{2 \tan B/2 \tan \theta}{1 - \tan B/2 \tan \theta}$$

where B = angle between lines on the two films and θ = angle of deviation of the fringe from the normal-to-the-bisector of angle B.

Some angle calculations made on the Moire pattern produced by recordings from recorder No. 5 indicate a transient of approximately 2% occurring at a rate which suggests that it is caused by the switching of the loop sensors. Tests are planned on recorder No. 6 to determine if this is indeed the cause.

In adjusting focus and making other observations through the microscope, it is very useful to move the trace at right angles to itself across the field of view at a slow rate to form a raster.

This permits viewing each picture element (i.e. each dot in the 30 megacycle locked oscillator signal) isolated in time. In the normal viewing mode the position or shape of the dot is modified possibly by hum fields; but this cannot be seen because the eye integrates the image over several scan intervals. By stretching the dots out into a line pattern with the slow sweep technique, the magnitude of the hum field can be determined and the effects of attempts to reduce the disturbing field immediately evaluated. This technique produces an image similar to that which is produced on the film as it is moved past the exposure point, but with the advantage that the image can be directly viewed rather than waiting for the processing of film.

NEW HEATER CIRCUIT

The power supply providing DC heater voltage to the CRT and focus modulator tube has been "beefed-up" throughout. Rectifier and zener reference diodes have been changed to higher current versions, the transformer used now has a higher current capacity; the regulator transistor has been changed from a germanium diamond package type to a silicon stud-mount type.

H CATHODE RAY TUBE POWER SUPPLY

The high voltage power supply furnishes the screen voltage, the focus voltage including dynamic focus, and the first anode voltage to the CRT (WX-4903, 576R725) in the recorder. Both electrical and mechanical requirements for this power supply are very severe and a satisfactory high voltage power supply has not yet been obtained.

The first high voltage power supply was made by AMP, Inc. of Elizabethtown, Pennsylvania. At least one failure has occurred in every supply received from AMP. They have missed their shipping dates by 3 to 6 months, and have refused to try and solve any of their design flaws.

The second attempt to produce a power supply was made by Kaiser, Inc. of Union, N. J. This company has worked closely with Itek to solve the problems. Although these supplies did not operate correctly at first, they have come very close to meeting the design specification. However, after a major redesign within the past month all of these redesigned supplies have failed, except the one in use on the Westinghouse Flight Test program. These failures have been returned to Kaiser for repairs. During this past month Kaiser, Inc. has been purchased by another company. The new company plans to move the present Kaiser facilities to upper New York state with the result that the present employees are finding new employment. Therefore the conclusion is that Kaiser can no longer be considered a reliable source for the high voltage power supply.

WESTINGHOUSE HIGH VOLTAGE POWER SUPPLY

The design of a power supply was started at Westinghouse after the first Kaiser design did not work. Once the breadboard design showed encouraging results ,then a detailed layout and packaging of this high voltage supply was begun. The drawings were finished this month and the model shop was authorized to build one unit. All electrical parts necessary for one unit along with spare parts are on order. Testing and final potting should be finished by the end of November. A dynamic focus circuit has been built and is operating in the laboratory. The output of this circuit into a 56K load is a near perfect parabolic waveform, whose amplitude is variable from 0 to 160 volts. The circuit uses no vacuum tubes and all transistors are silicon. This circuit can also be adjusted to correct the waveform if the trace is not symmetrical to the center of the CRT. This circuit will be back fitted into the high voltage power supply.

I SYNCHRONIZER

Range Mark Generator units have been added to the two deliverable systems. Wiring to the Frequency Generator unit has been reworked to conform to latest changes.

FREQUENCY GENERATOR

The breadboard unit has been assembled and tested. Noise in the Tracker reference section which prevented loop lock-up was removed by an impedance level adjustment reducing the tendency toward oscillation. Fabrication of the deliverable Frequency Generator is 80% complete. The Fixed Frequency chassis and the Variable Frequency chassis for the Environmental system have been reworked to be compatible with the new Frequency Generator configuration. This same rework will be accomplished on the Flight Test units when the redesigned Frequency Generator unit is installed.

J TRANSMITTER

Since return of the breadboard transmitter from S.F.D., it has been used to evaluate pulse forming networks, chokes and diodes. Several modifications have been made on the two deliverable transmitters, including installing new charging diodes and choke, modifying brackets to reduce arcing and adding wires for test.

K SWITCH TUBES.

Dump tube WX-4554-11 had an initial antenna peak power gain above the reference input of +4.5 db with the unfired to fired phase shift of $\frac{\lambda g}{4}$. After six hours of testing this tube was set up on the traveling -wave resonant ring for a life test study. At this time the antenna peak power gain was +1.5 db above the reference input signal. After 68 hours of operation the antenna peak power gain was +1.2 db. The fall time of the antenna spike had increased by 2 nsec. After 97 hours of operation the antenna peak power gain was -0.3 db. The rise time had increased by 2 nsec. on the antenna spike, and the pulse was not as "clean" as at 68 hours. Some auto-triggering was noted. After 103 hours of operation the antenna peak power gain had dropped to -3.3 db above the reference input. The spike was unstable on the rise and fall slopes and the isolation has changed from greater than -20 db to -16.5 db. The tube autotriggered frequently if it was unfired.

It is concluded that erosion of the dome tips changes the dome gap spacing. This in turn changes the unfired to fired $\frac{\lambda g}{4}$ phase shift, thereby reducing the antenna peak power gain. The erosion of the dome tips is also the probable cause of the unstable rise and fall times and the frequent autotriggering.

As the result of an investigation on the characteristics of dome tip materials and sputtering, three conclusions are drawn:

1. Materials which are sintered and not homogeneous have a higher sputtering coefficient than materials which are drawn or arc-cast.

2. A hemispherical dome-tip configuration has lower sputtering coefficient than a flattened dome-tip configuration.

3. The sputtering coefficient is dependent on the tip material. A theory that elements whose "d" subshell is completed have high

sputtering coefficients was investigated. There are indications that this theory is valid since brass and copper dome tips eroded severly as compared to tungsten and rhodium dome tips, which were operated for the same duration of time and under the same conditions. Tests are being conducted using a removable hemispherical dome-tip of arc-cast molybdenum to investigate sputtering problems further. No further work is planned on switch tubes on this contract.

L MOTION COMPENSATION

The first motion compensation unit (MCU) has been operated at Westinghouse. It is at least functional in all respects except the antenna position control.

The hydraulic actuator available for this operating temperature has a poor high frequency response compared with the F101 flight test model. Without elaborate lead networks this will have a performance just marginally acceptable for the present assumptions of aircraft motion. The necessary changes to the M.C.U. to provide this actuator with this degree of performance have been sent to Honeywell for the following units.

M RADOME

The frame for testing an entire radome with the antenna is complete and the full radome has been received. The final determination of the effect of radome and the aperture blocking radome support structure upon antenna side lobes and gain will be determined.

N FIELD TEST EQUIPMENT

The System Test Set composite testing is completed and all systems of the equipment are functioning properly. Modification of the RF Stability Analyzer is completed and the test of this unit indicates that all the problems involved previously have been corrected. Certain system components are being gathered to provide preliminary test data until a complete system is available. The System Test Set will be moved to the Hangar for a series of tests on the Flight Test Radar.